SMOKE MONITORING WITH AVHRR SATELLITES

Prepared by

David A. Prevedel

USDA Forest Service

Region 4 IST GIS Staff

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We have been using satellites (NOAA AVHRR) to monitor fire activity for the last few years. An emerging application using these technologies is the monitoring and management of smoke from wild and prescribed natural fires. Concerns are reaching political proportions in determining who's smoke is effecting whom.

Smoke is significantly affected by wind and other weather variables. Existing smoke models using linear predictions may not truly define this. By using satellite data with ancillary weather data including the position of low and high pressure systems, ground winds, upper atmosphere winds, frontal approaches and passages, etc., smoke monitoring and management can be more accurately portrayed.

More correlation needs to be done with actual observed smoke and weather conditions. Smoke can be a narrow plume rising high into the atmosphere or a fan shaped plume at lower altitudes. Factors effecting how these plumes disperse or persist, or even the significance of terrain and fuel type, are not fully understood. Often, smoke will remain intact and follow weather patterns for days or weeks while other times, it disperses within a few hundred miles of the source. Internationally, the summer of 1998 saw significant smoke enter the United States from Canada and Mexico.

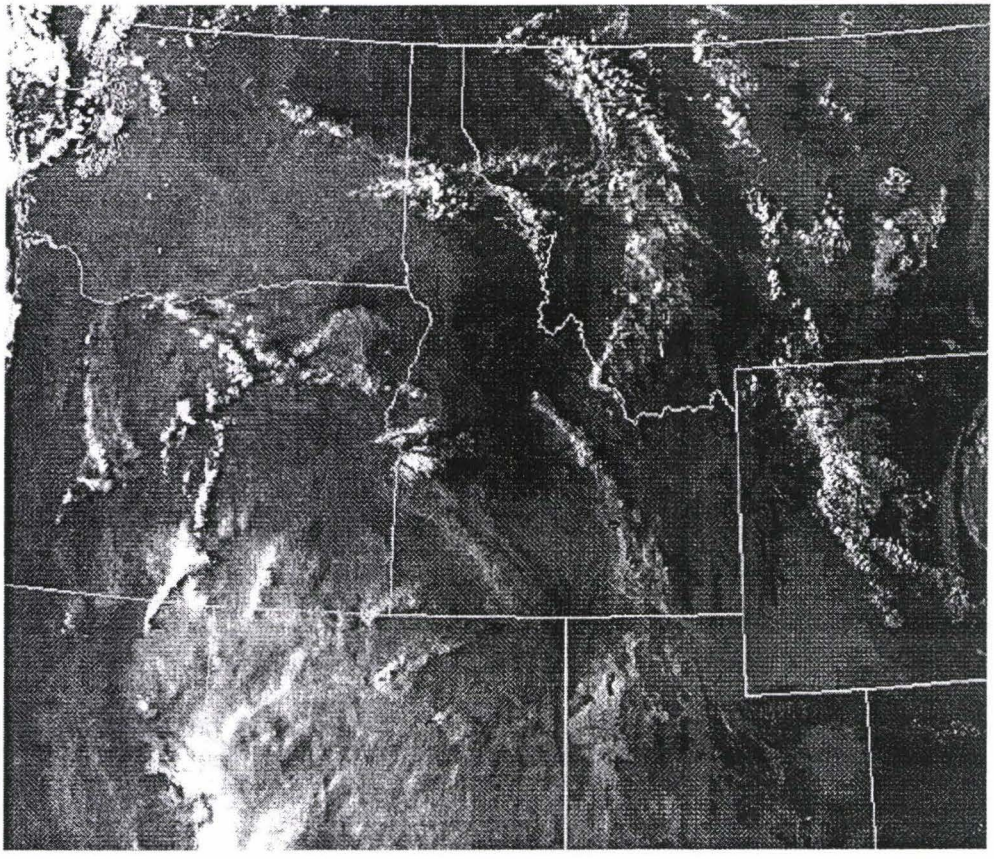
Controversy and conjecture continues to occur between Federal Agencies and States over degradation of air quality by smoke from public lands. However, as noted in the images presented, the burning of crop land residue from agricultural lands, particularly in the Northwest states and central Canada, present a very significant source of smoke that has previously been unevaluated.

The smoke images in this presentation were taken from NOAA-12 and NOAA-14 of the TYROS (AVHRR) satellite platforms and represent a chronology of Weather, smoke, and fire activity across the Western United States from August 29, 1996 to September 5, 1996, and from April 29 thorough September 21 of 1998. Images were processed in Ogden Utah following capture by a commercially purchased receiving antenna. Of the five frequencies or bands received from AVHRR platforms, Band 1 is used to view visual smoke and Band 3 for Infra Red fire locations.

For additional information, contact Dave Prevedel at 801-625-5660 (IBM dprevede/r4) or e-mail to david.prevedel/r4@fs.fed.us. Copies of the images may also be obtained from the Forest Service Intranet Web Site at: http://fsweb/r4.fs.fed.us/coe/index.html.

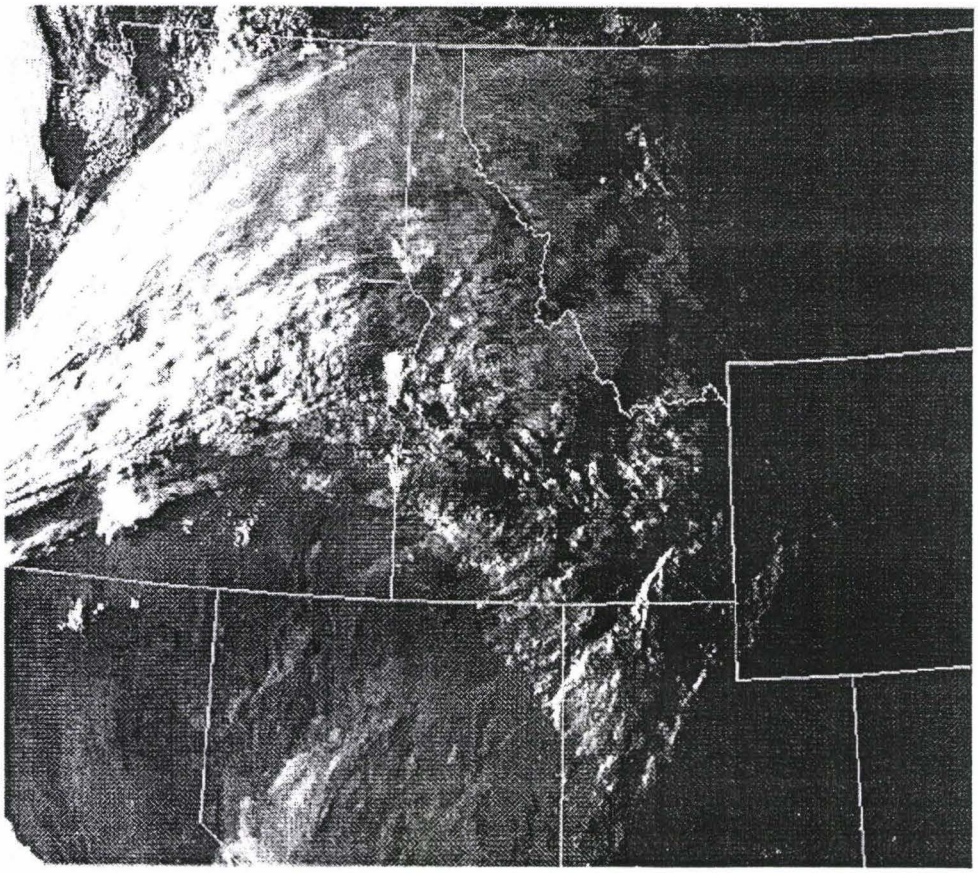
THE 1996 FIRE WEATHER SEQUENCE

1996 was an record fire year. Wildfires burned throughout the Western United States. The following sequence of images were collected during one of the peak fire occurrence periods in which weather played a major role.



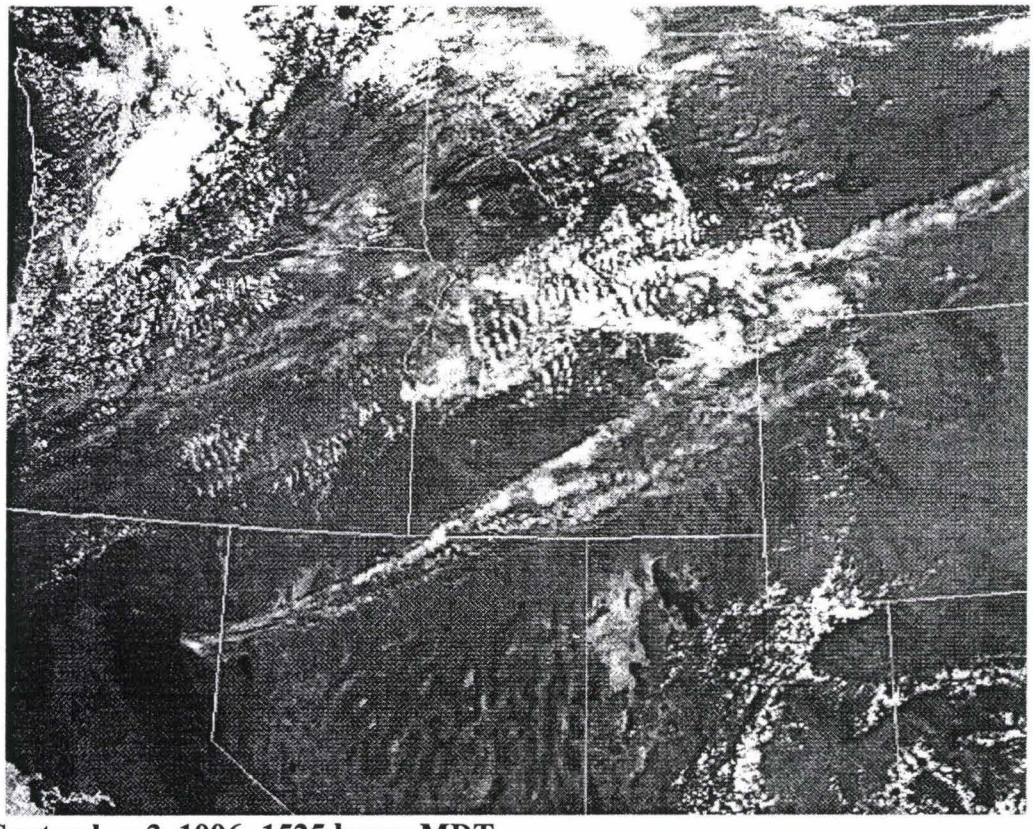
August 29, 1996 - 1925 hours MDT

High pressure dominates the Western US. Note the clockwise rotation of smoke plumes center over Nevada. Fire activity is at its peak in Oregon, California, Nevada, and Idaho. Smoke plumes remain intact for hundreds of miles before dissipating in the upper atmosphere.



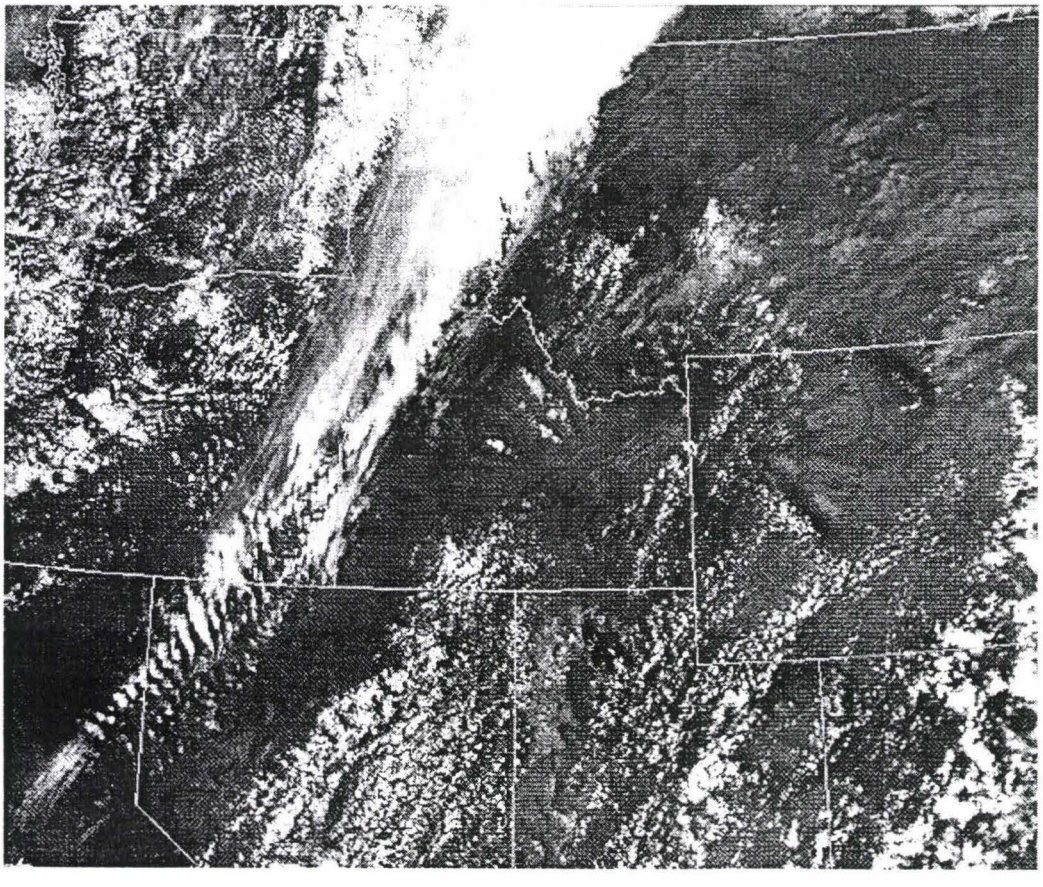
September 2, 1996 - 1938 hours MDT

A storm front has enter the Pacific Northwest. Note Southwestern flows over California causing extreme burning conditions. Smoke is encompassing the Reno Basin and progressing North and east with the high pressure system now over Nevada.



September 3. 1996- 1525 hours MDT

The high pressure system has moved over the Four Corners area of Utah, New Mexico, Arizona, and Colorado (note the clock-wise rotation). Note the Pacific front has progressed eastward to almost Boise Idaho. Note the burning of field stubble in Western Oregon and the smoke dispersal with the higher winds. High winds aloft are carrying smoke from Central California to Yellowstone NP. Note how the smoke plume is drifting back towards the North as the high pressure system moves back into the Great Basin from the Southeast. Central Idaho fires and other Montana fires have produced smoke that drifts across Montana along the front edge in a northeastern direction.

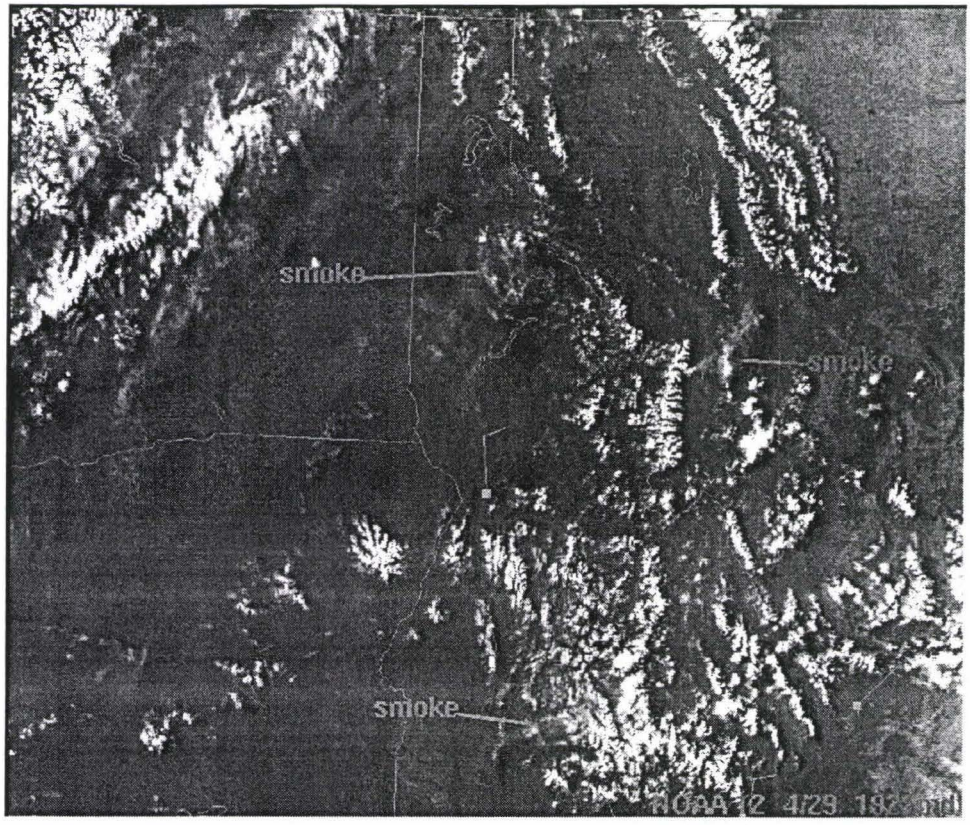


September 4, 1996 - 1514 hours MDT

High pressure has pushed the front further North. Extreme fire activity was experienced between the front and high pressure system in Idaho, Wyoming, and particularly in Southern Montana. Note the residual smoke covering most of Eastern Montana.

THE APRIL 1998 FIRE WEATHER SEQUENCE

During the spring and early summer of 1998, above average precipitation and fuel moistures in the Western United States made wildfire a rare occurrence. The exception being the Northern Canadian Provinces where large fires burn out of control most of the summer. The following images show three major contributors to smoke and particulates in the atmosphere between April 28 and May 5, and the subsequent smoke added to the Midwestern United States.

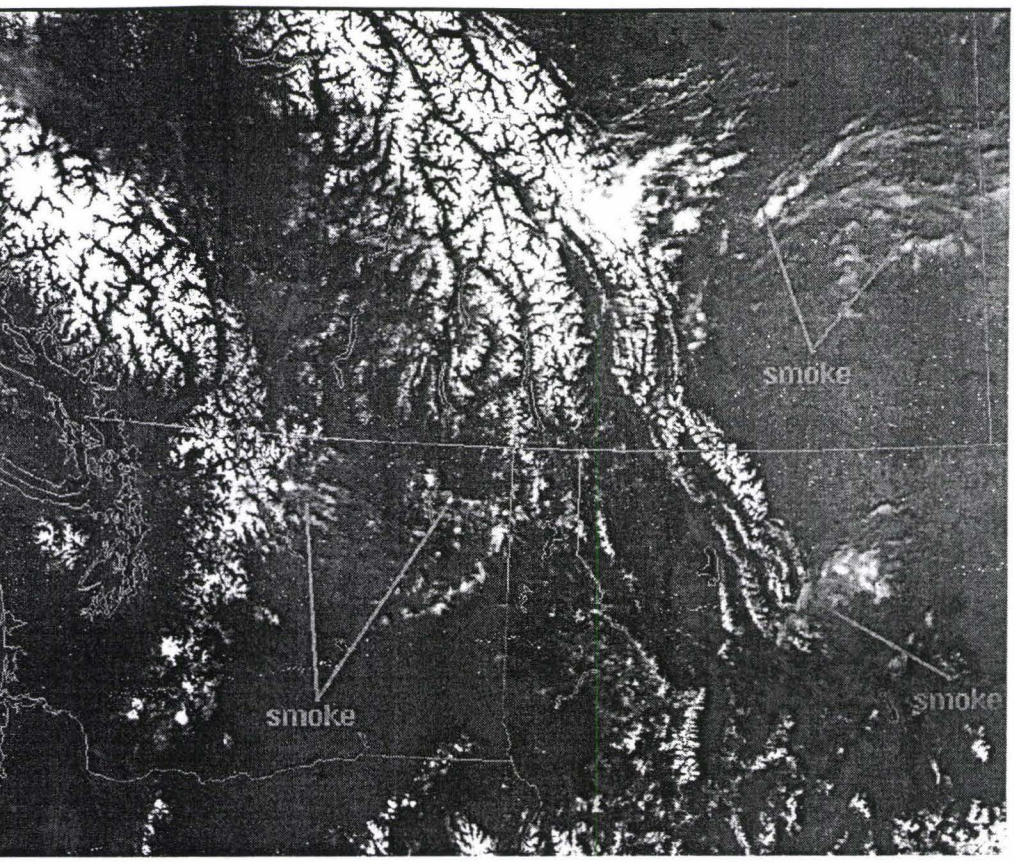


April 28, 1998 - 1922 MDT Smoke

Burns and smoke are visible from prescribe slash residue fires on the Boise NF, Bitterroot NF, and Northern Idaho National Forests. Winds are from the Southwest and West.

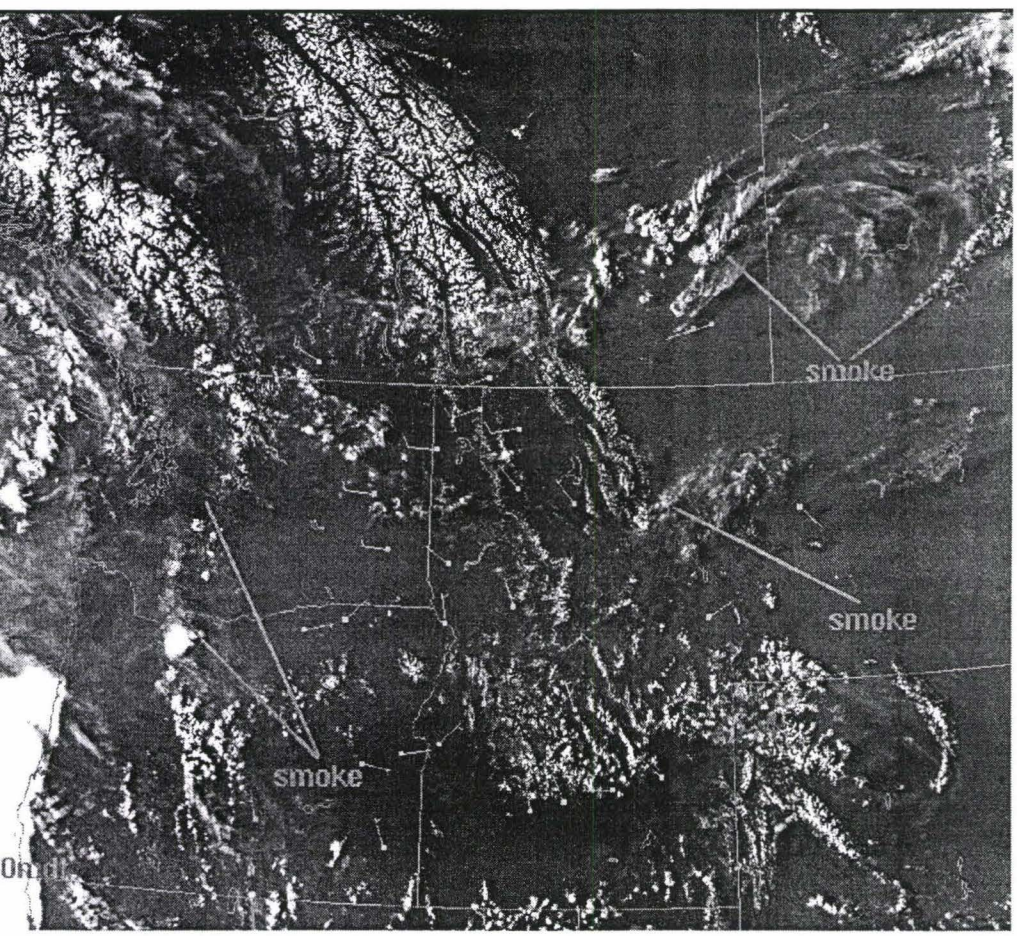
April 28, 1998 - 1922 hours MDT - Infrared

Infrared view of the area above showing heat generated by the prescribed fires in white. This data is from band 3 of the AVHRR image.



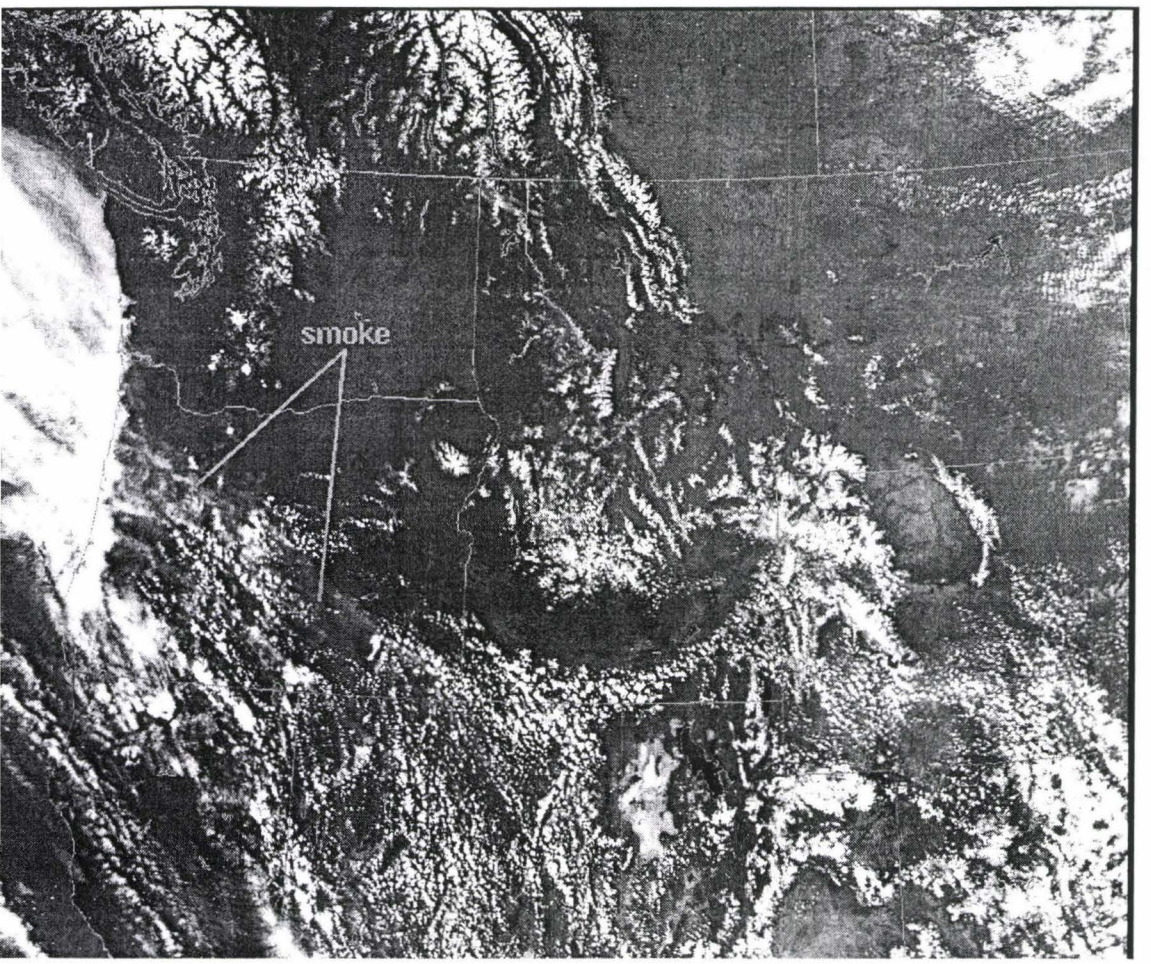
April 29, 1998 - 1651 MDT

A large prescribed slash burn is occurring on the Helena NF and note the Agricultural field fires in Alberta and Saskatchewan. Field fires are also occurring in north=central Washington.



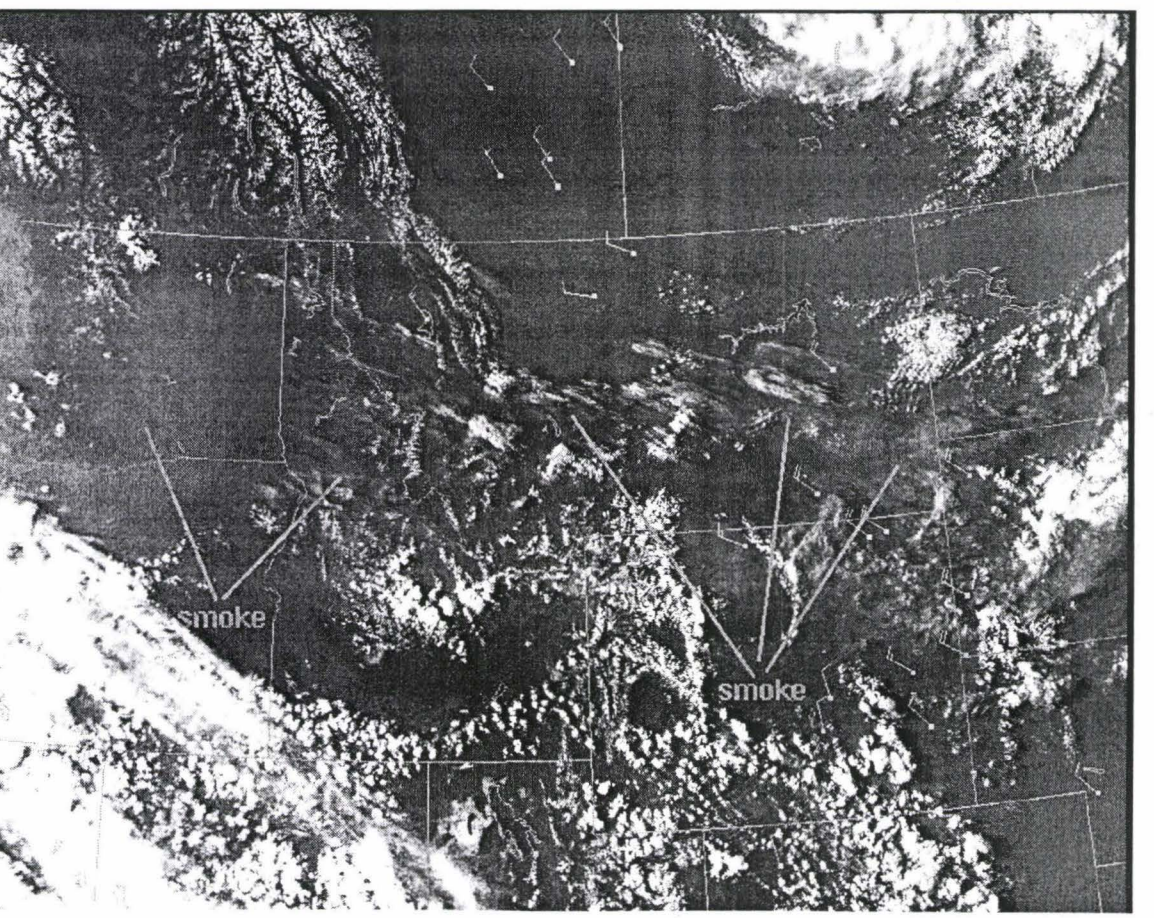
April 29, 1998 - 1900 MDT

A high pressure system has entered the Pacific Northwest. Note the western flow and the smoke now covering Washington State. The large prescribed slash burn is still occurring on the Helena NF and now the agricultural field fires in Alberta and Saskatchewan are rotating clockwise in the upper atmosphere but flows are eastward in the lower atmosphere.



April 30, 1998 - 1548 MDT

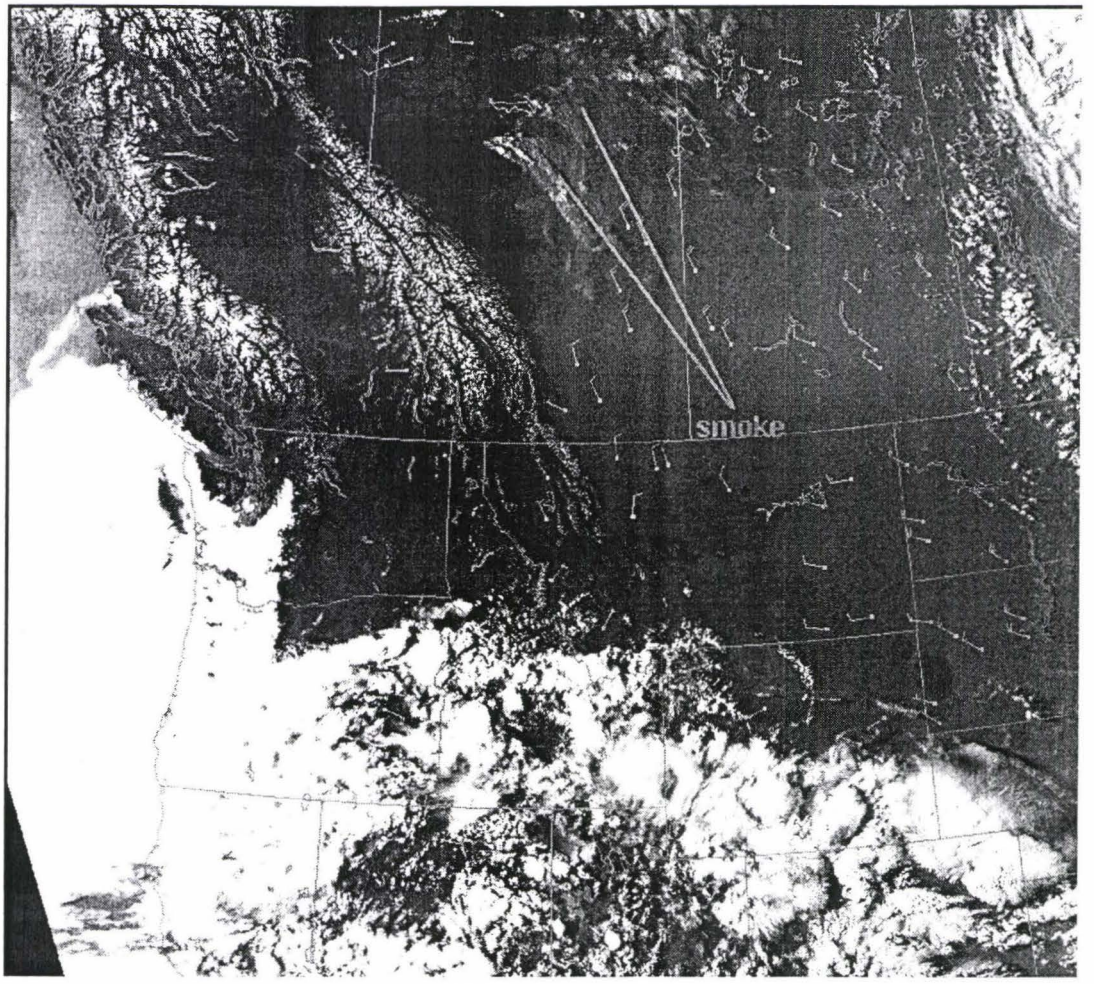
By this next day, the smoke in the Pacific-northwest has shifted southward with the main air flow. Note that eastern Montana has cleared of smoke.



April 30, 1998 - 1840 MDT

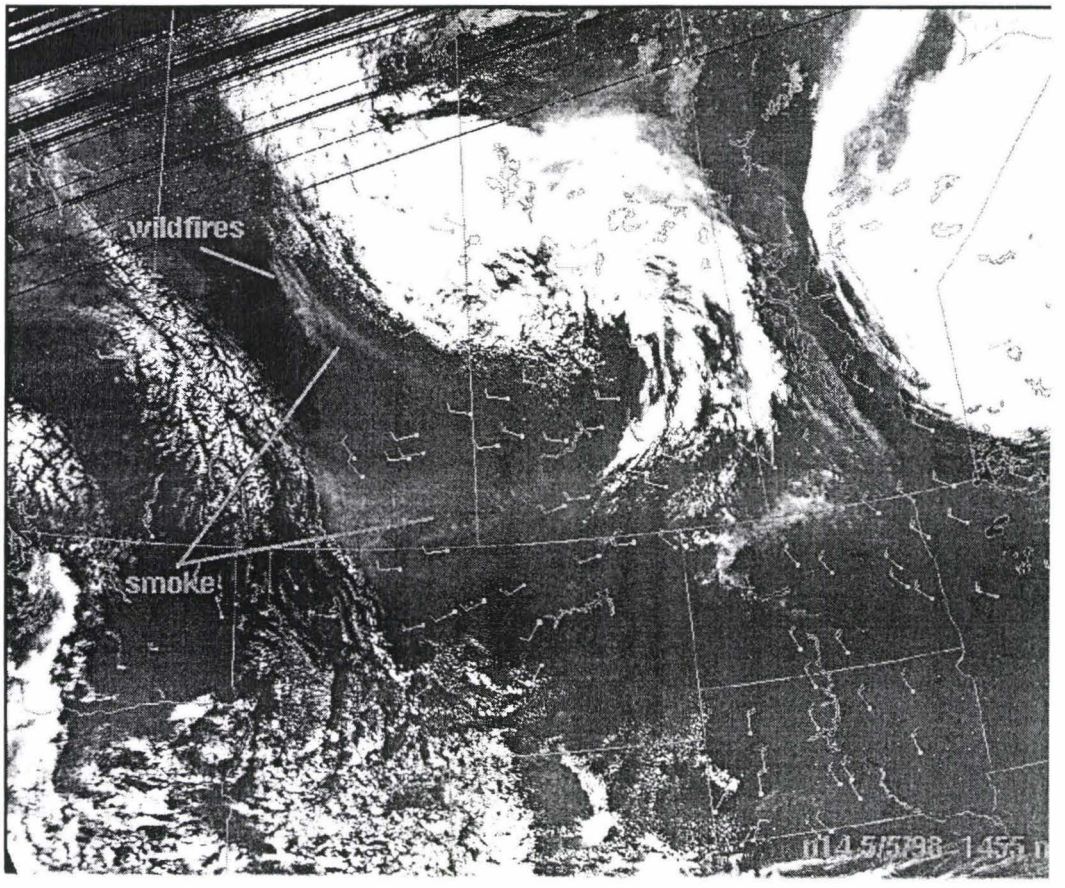
Just three hours later, note all the agricultural field fire ignitions in Idaho and Montana. Air flow is directly from the west.

THE CANADIAN WILDFIRES



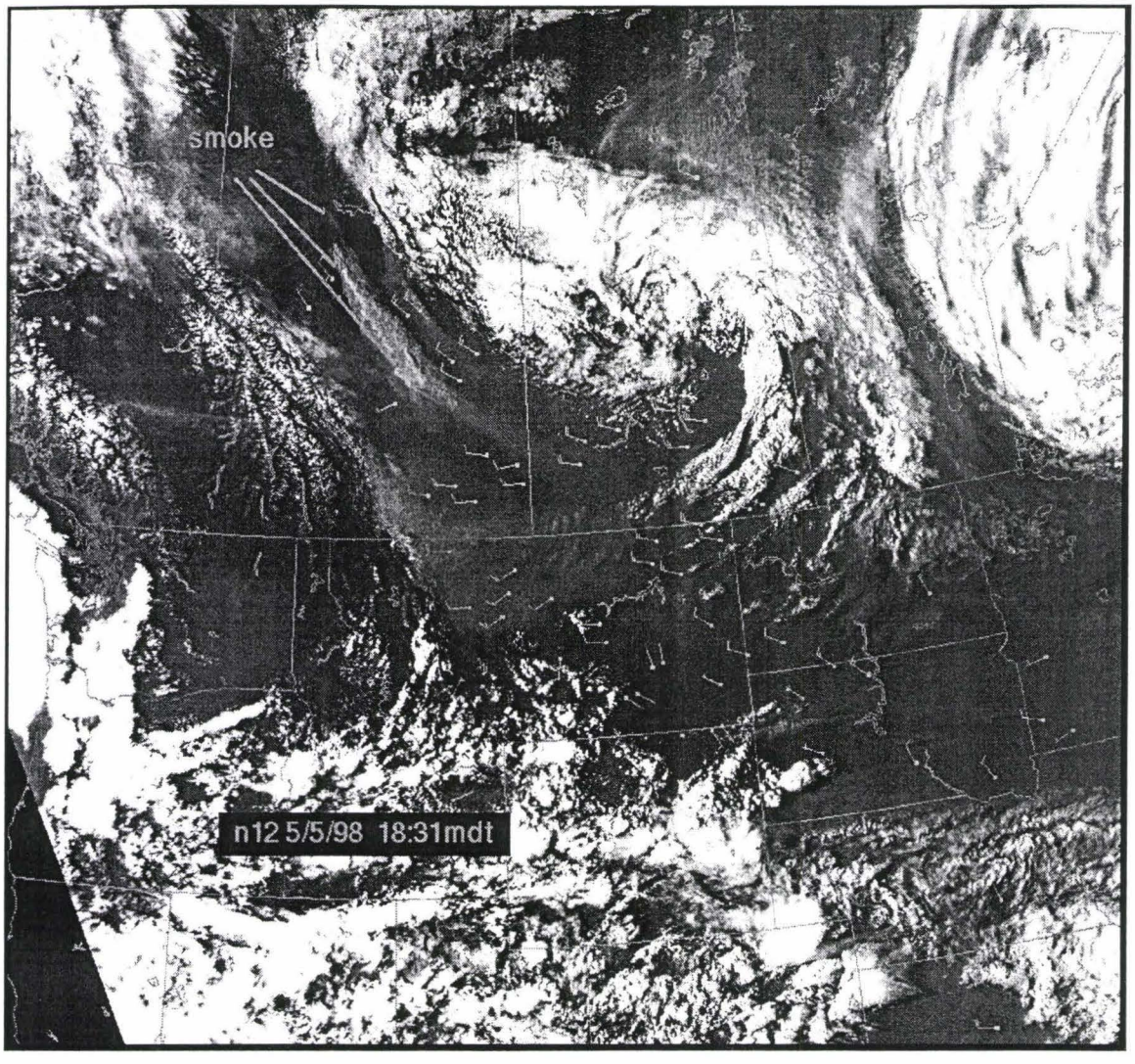
May 4, 1998 - 1850 MDT

Large wildfires are occurring just below the Arctic Circle in the Alberta Province of Canada. Air flow is from the West. Note southward flow as indicated by wind bars.



May 5, 1998 - 1455 MDT

The air flow has shifted from the North and smoke from the Canadian fires is starting to enter the United States. The Arctic low pressure system is sliding south.

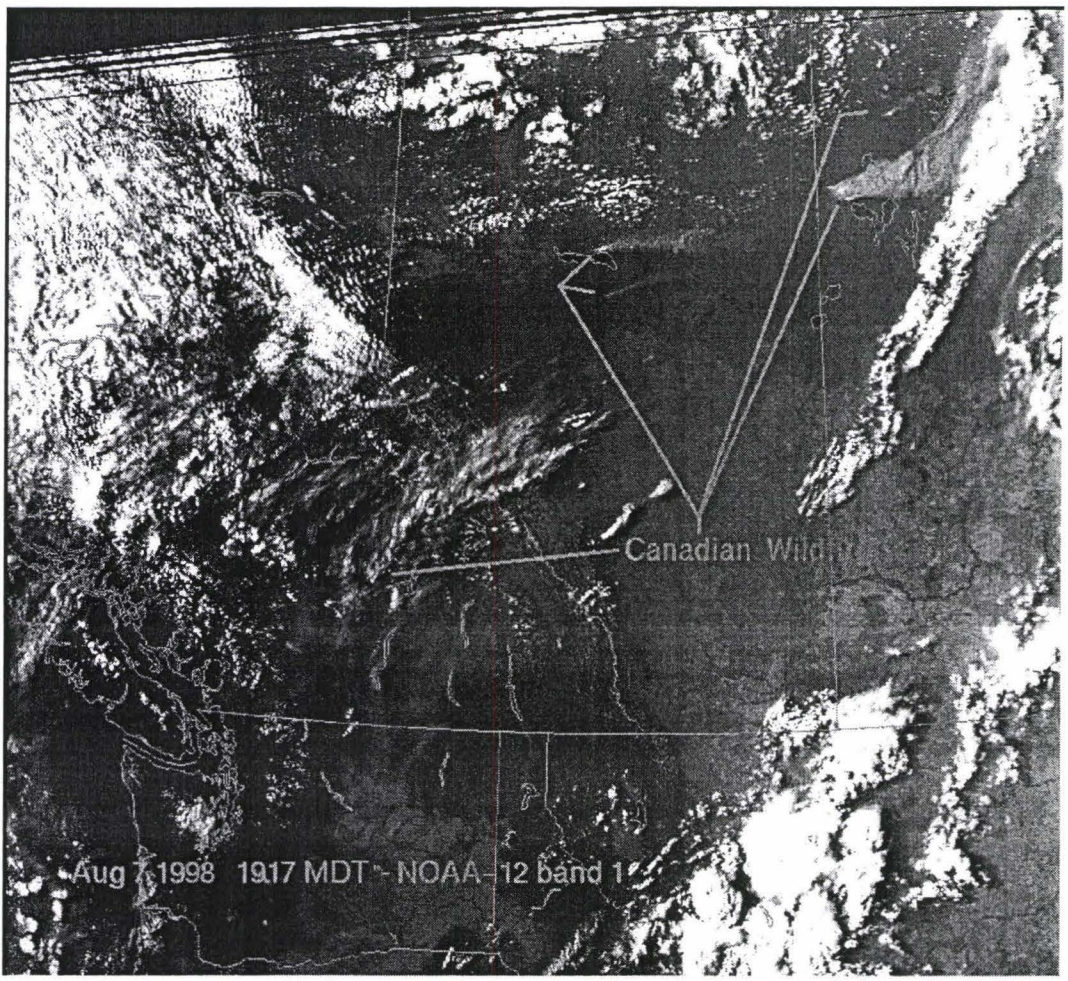


May 5, 1998 - 1831 MDT

By this time, the North-west flow has brought considerable smoke and particulates into the Mid-west and Great Lakes Ar-eas. Note the counter-clockwise rotation around the Arctic low pressure system.

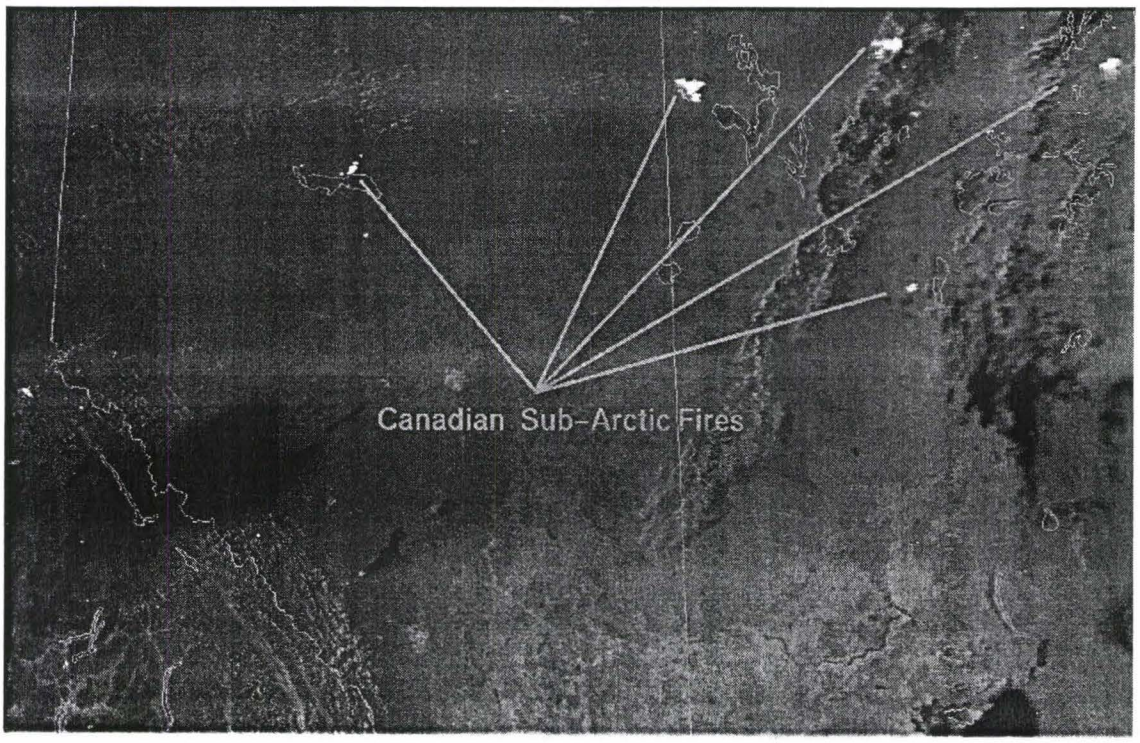
THE EARLY AUGUST 1998 FIRE WEATHER SEQUENCE

This fire sequence shows smoke dispersal as effected by wind associated with westward (clockwise) flows and convections around pressure systems . During this time period, tropical depressions moved over the Intermountain area from the South



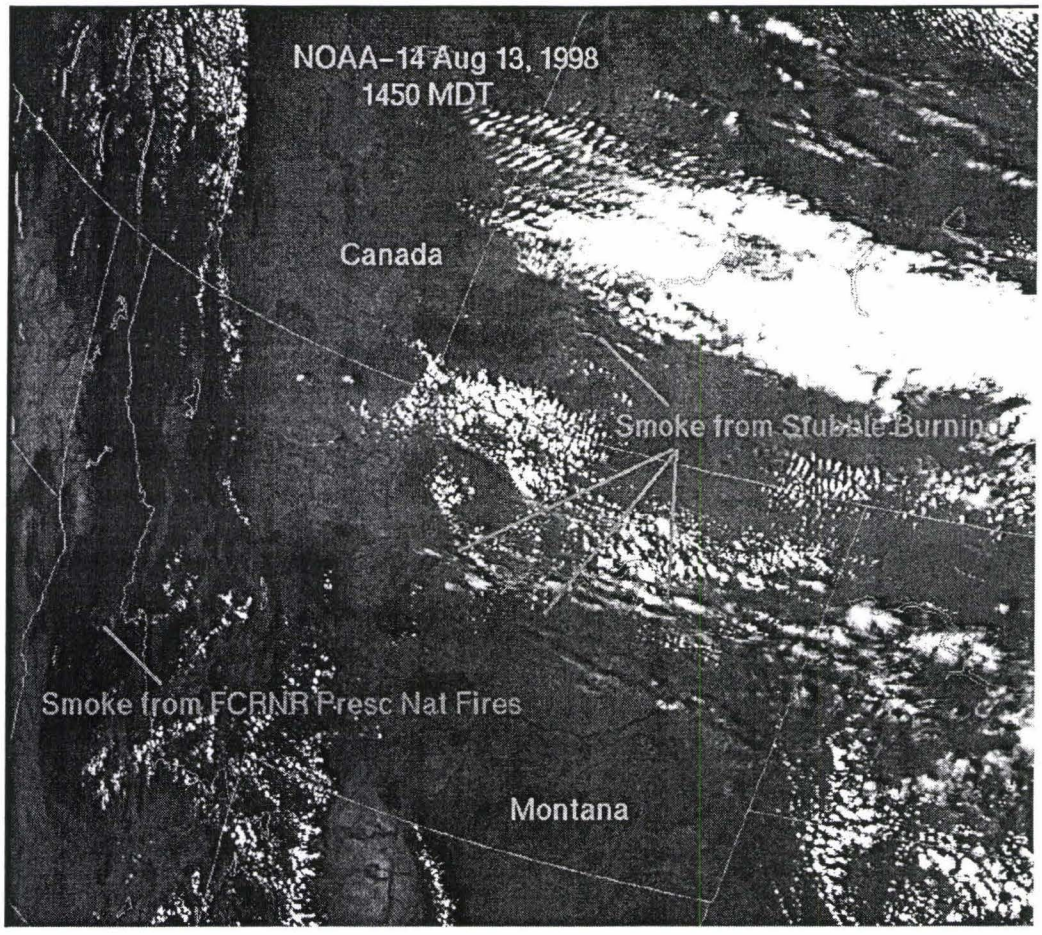
August 7, 1998 - 1917 MDT

Strong winds north of the US-Canadian boundary are pushing the fires in the Canadian Rockies and Sub-Arctic. Note the smoke trailing to the East of the large fires.



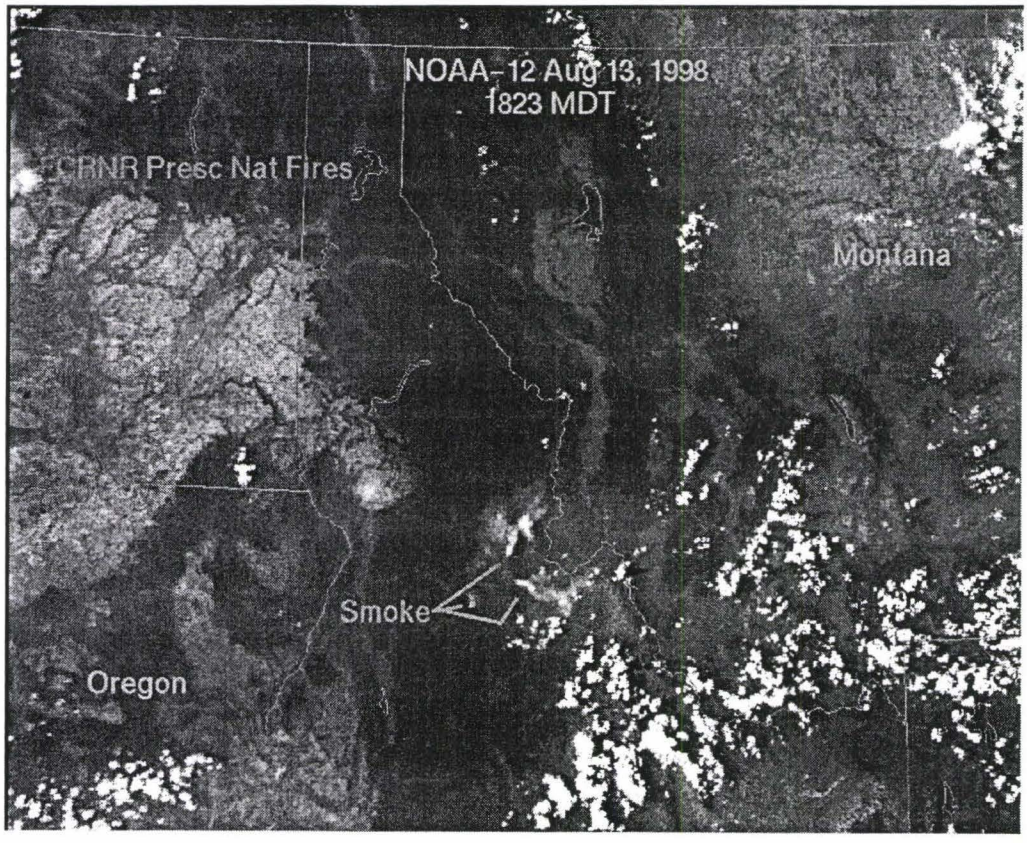
August 7, 1998 - 1917 MDT Infrared

Zoom in of the Canadian Subarctic fires showing size and blow-up conditions.



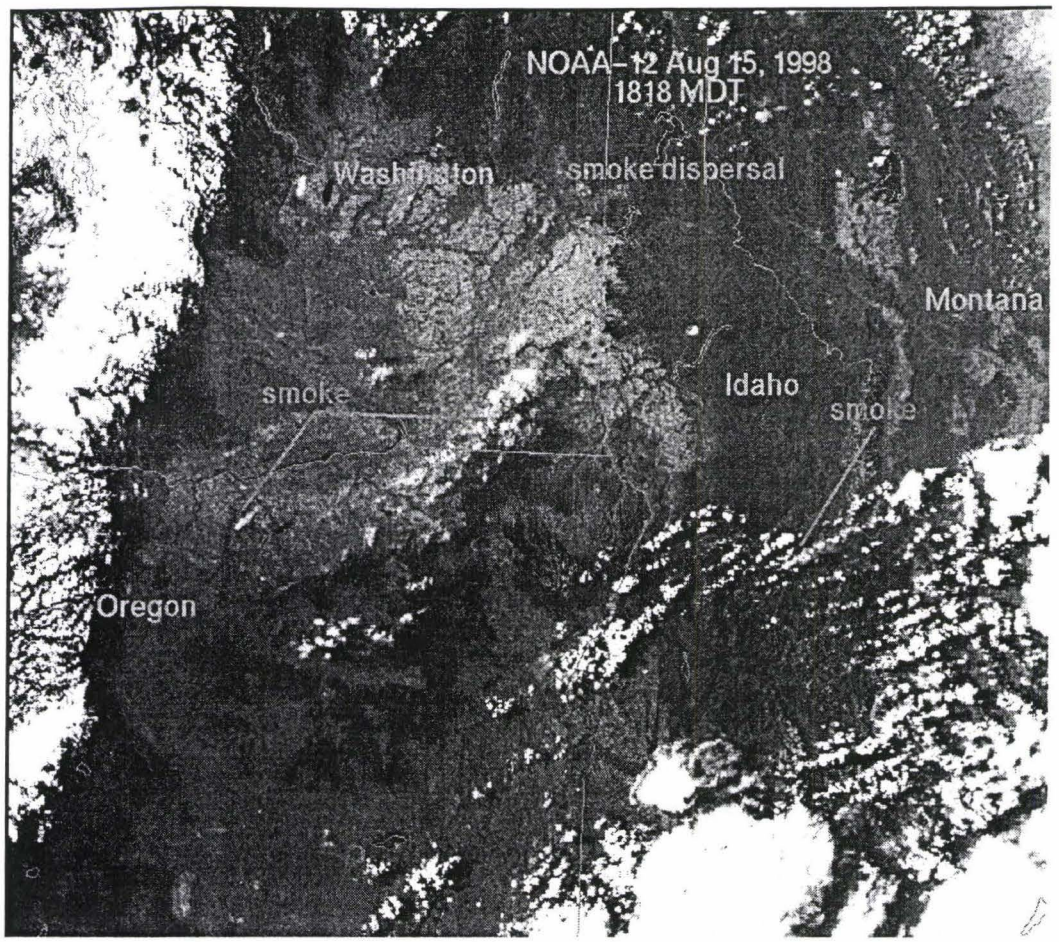
August 13, 1998 - 1450 MDT

High winds continue to carry the smoke eastward in the Canadian Provinces and United States. Note the agricultural field burning that is occurring extensively over much of Montana and North Dakota.



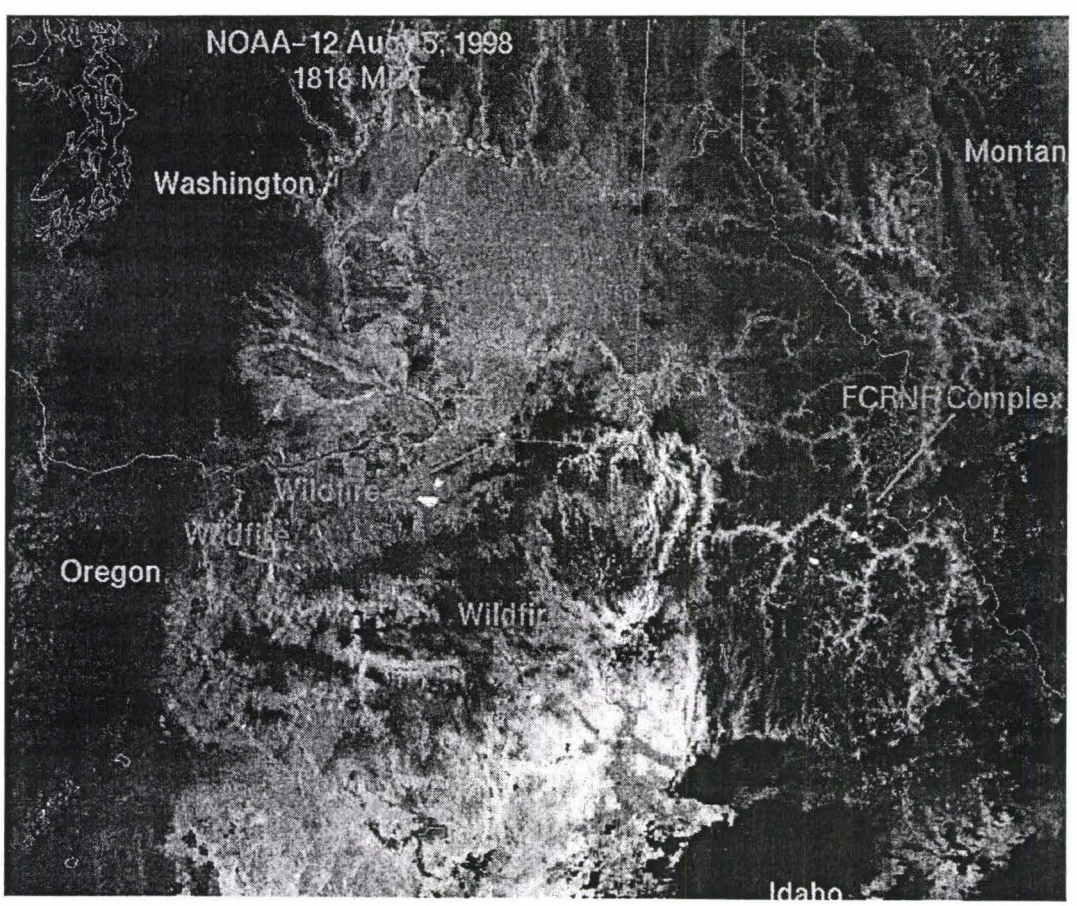
August 13, 1998 - 1823 MDT

About four hours later, the high winds aloft appear to have died down. The Prescribed Natural Fires in the Frank Church River of No Return (FCRNR) Wilderness are now visible and smoke is pooling into the higher mountain basins.



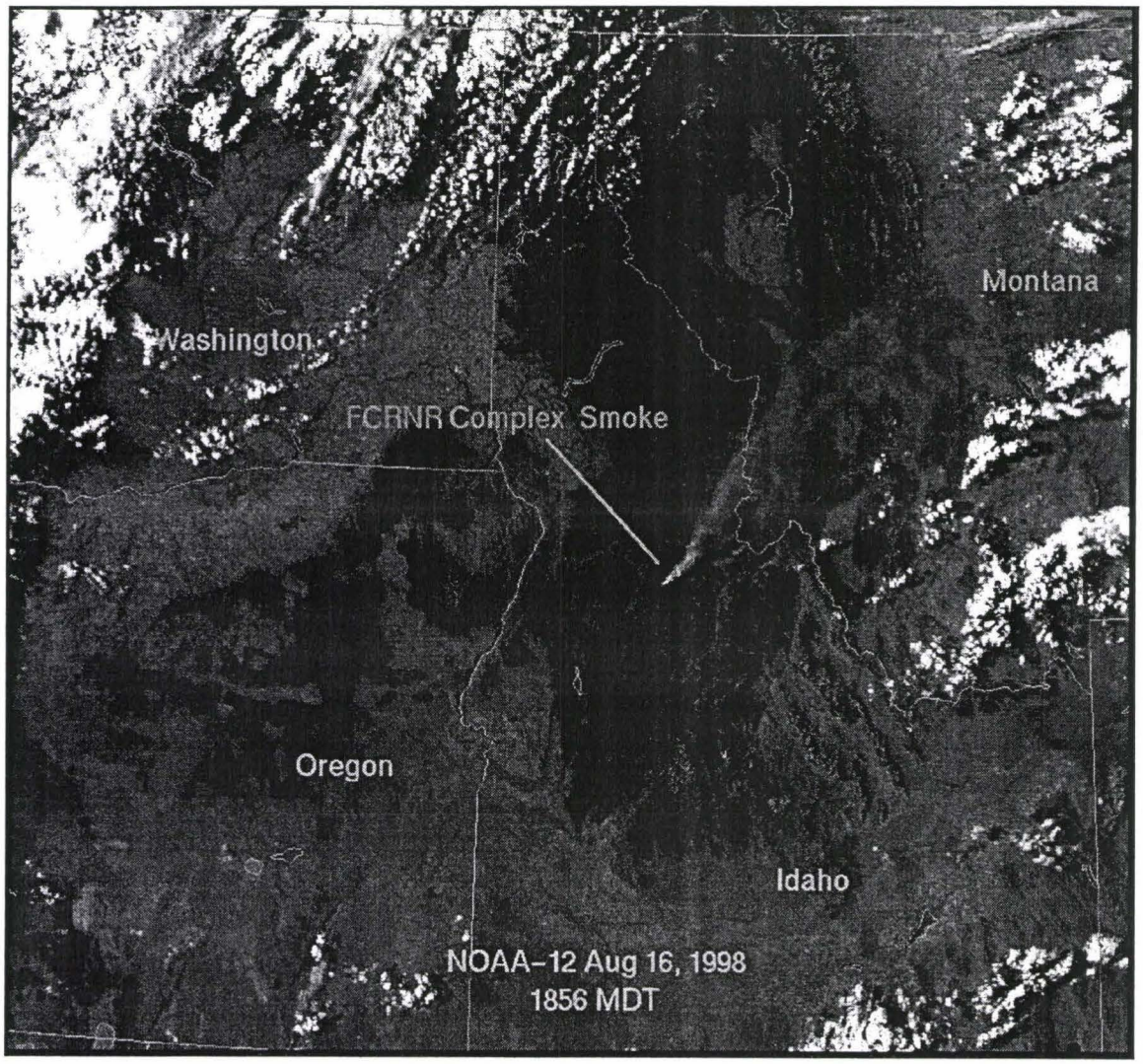
August 15, 1998 - 1818 MDT

Two days later, the tropical moisture has move back northward and is improving smoke dispersal. The FCRNR Prescribed Natural fires continue to burn as do numerous ignitions in Northern Oregon.



August 15, 1998 - 1818 MDT Infrared

Infra Red view of fire sites and fire activity.

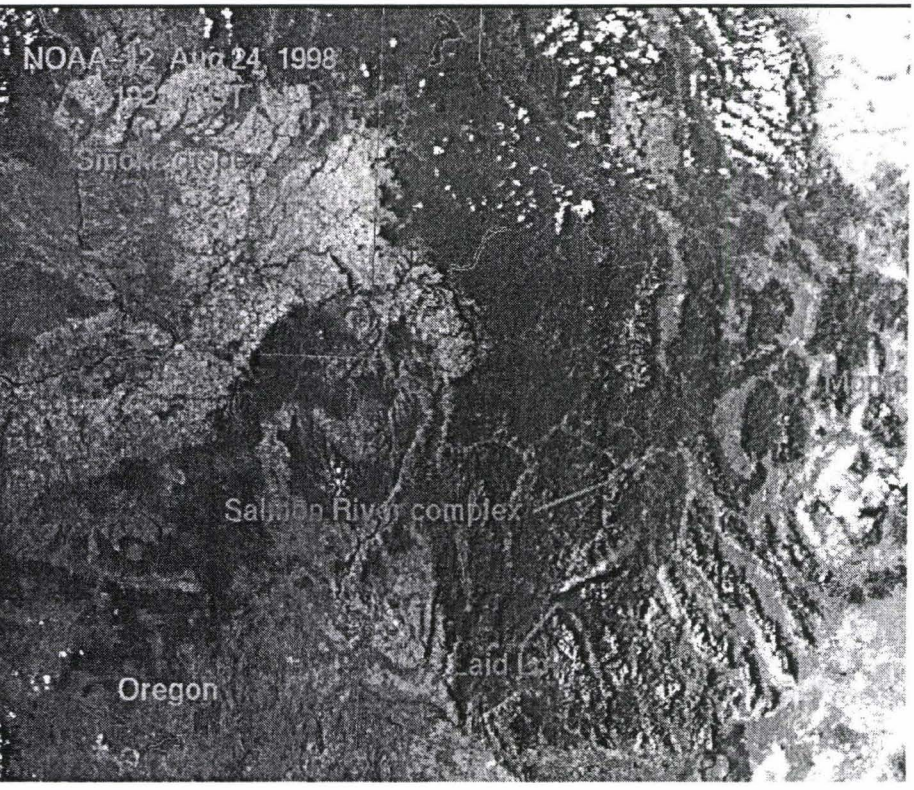


August 16, 1998 - 1856 MDT

The tropical depression has move to the East and smoke from the FCRNR wilderness is now more persistent. The fires in Northern Oregon appear to have been contained.

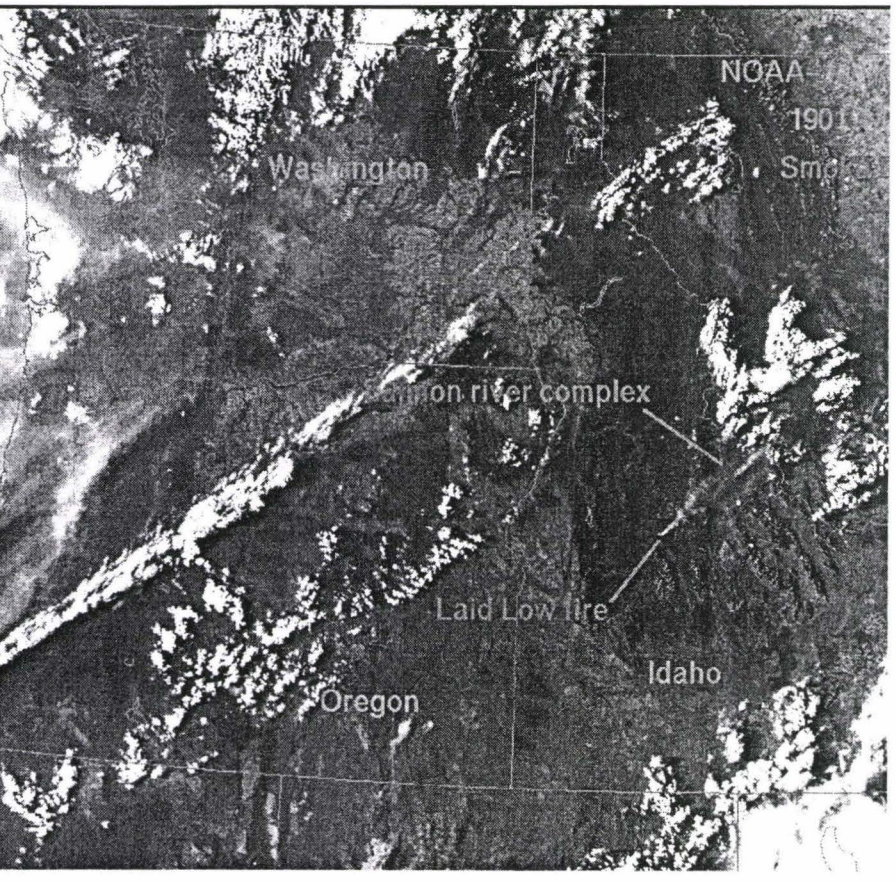
THE LATE AUGUST 1998 FIRE WEATHER SEQUENCE

The sequence is interesting in that it illustrates how smoke behind a frontal system is effected and just how persistent and intact smoke can remain in the atmosphere. In this case, the smoke was sucked in with a frontal passage from the Gulf of Alaska and ended up covering much of the Pacific Northwest and Intermountain Areas.



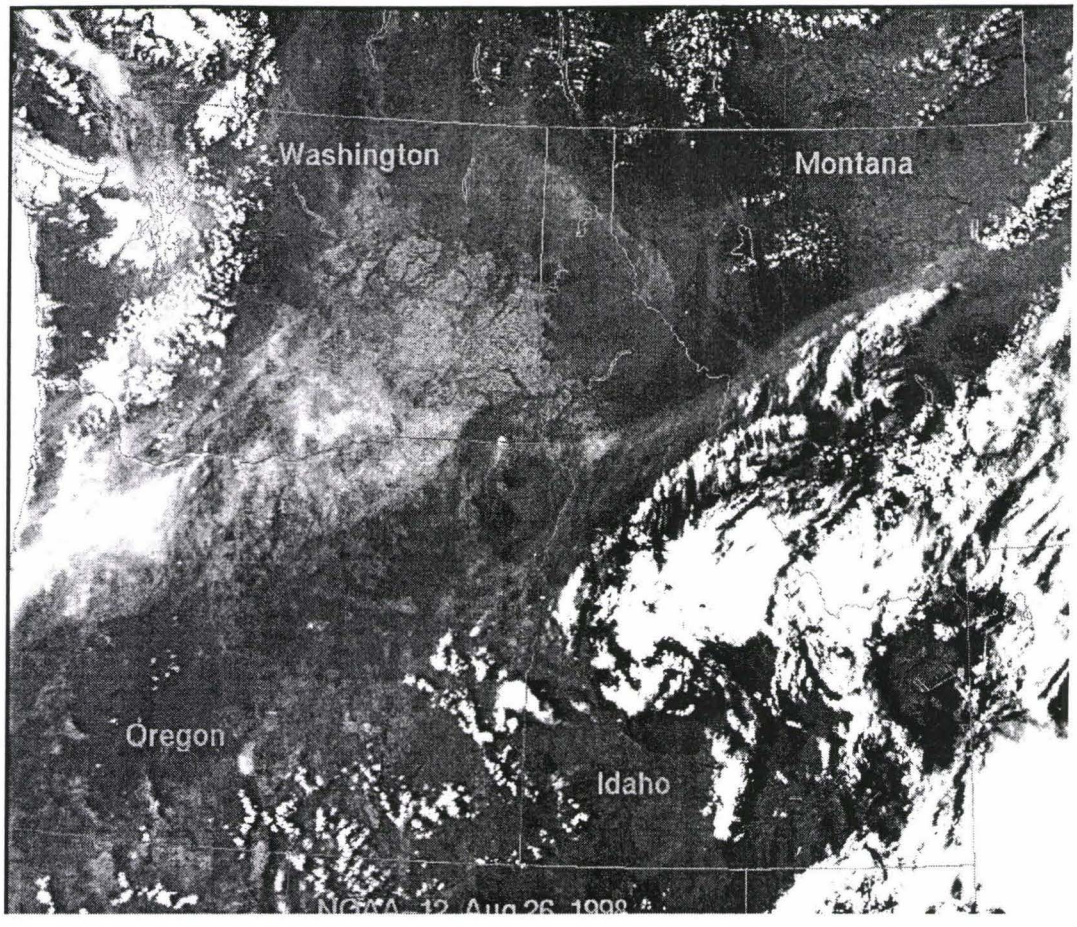
August 24, 1998 - 1923 MDT

A high pressure system dominates the intermountain area. Note the visible smoke from the prescribed fires associated with the FCRNR Wilderness.



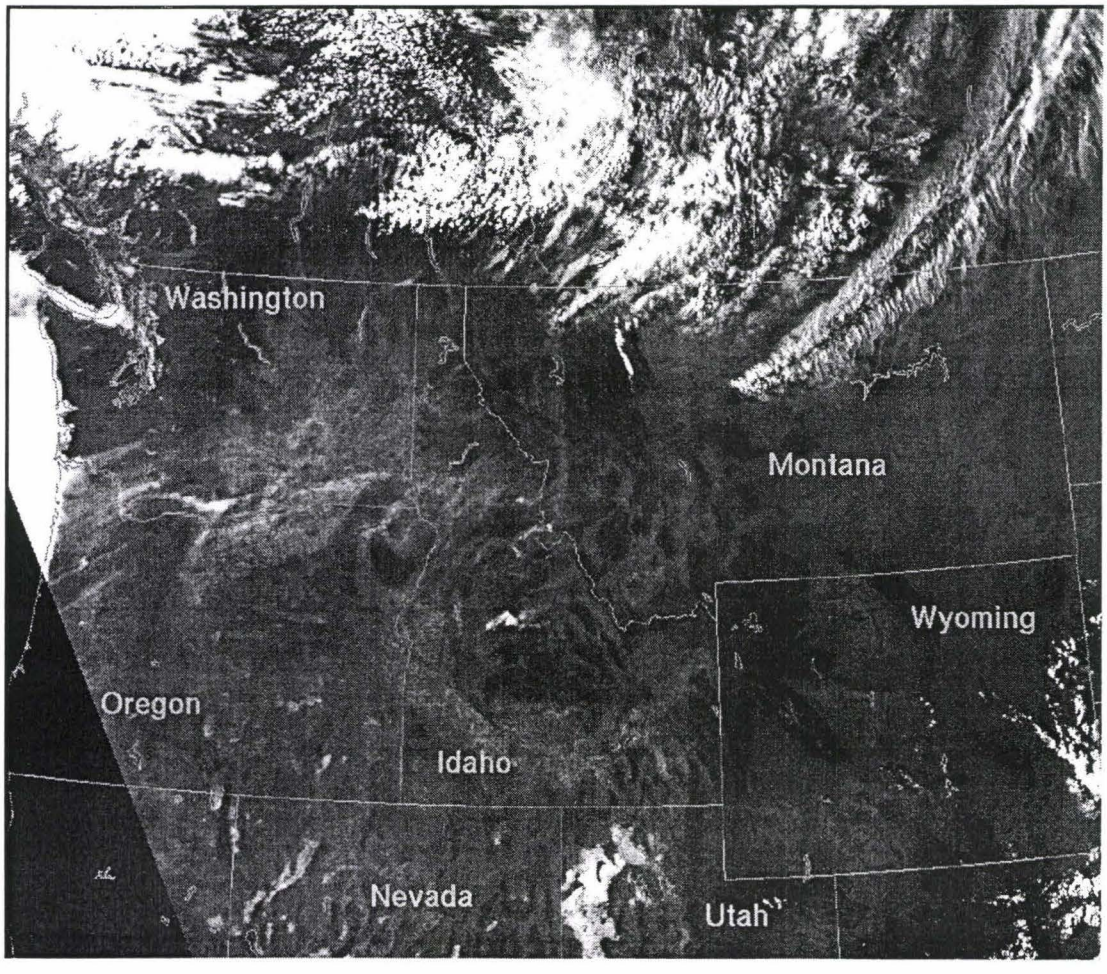
August 25, 1998 - 1901 MDT

A frontal system has entered the Pacific Northwest. Note the smoke following in behind this front.



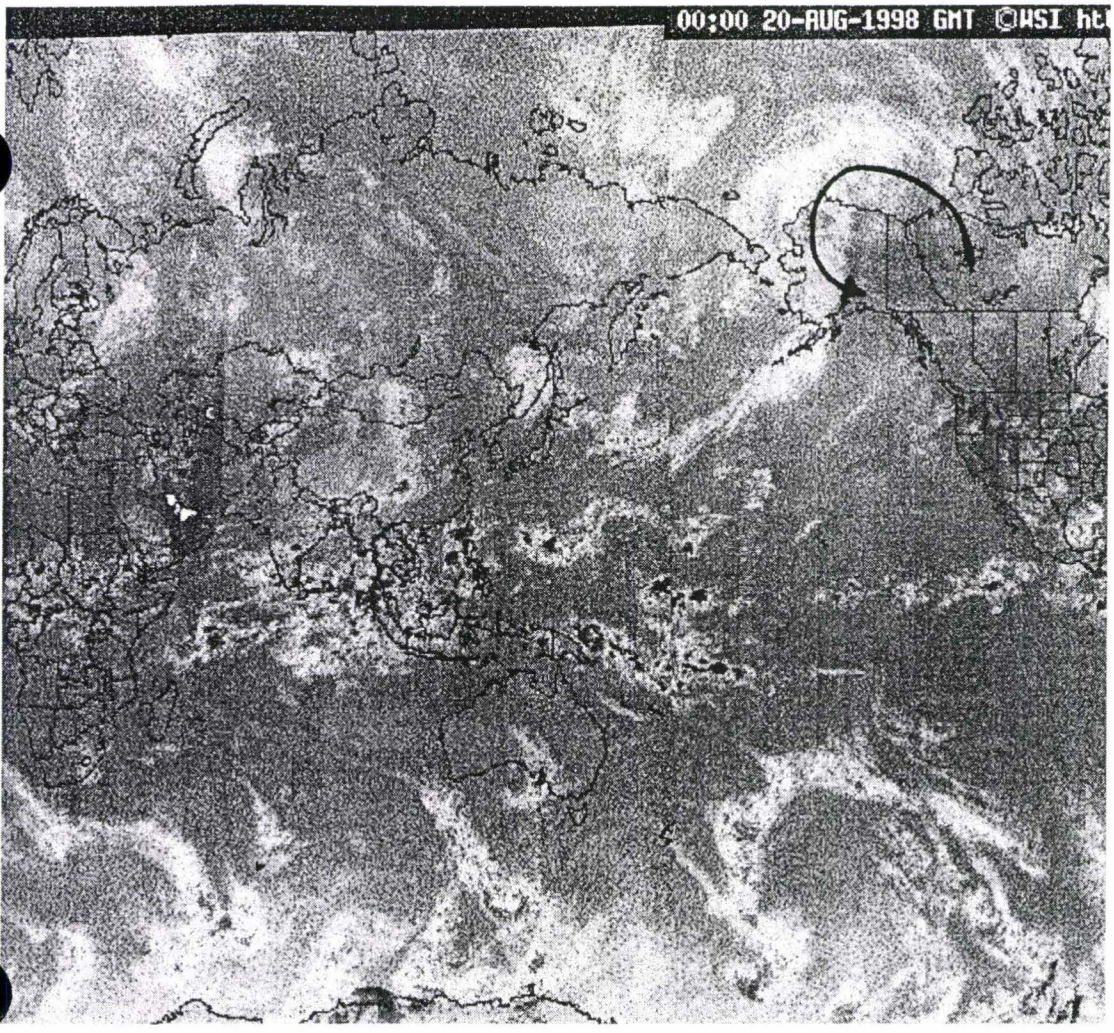
August 26, 1998 - 1839 MDT

Counter clock-wise wind currents from the front are contacting the clock-wise currents of the high pressure system. Note how the smoke accelerates along this contact zone and is stretched out into Eastern Montana.

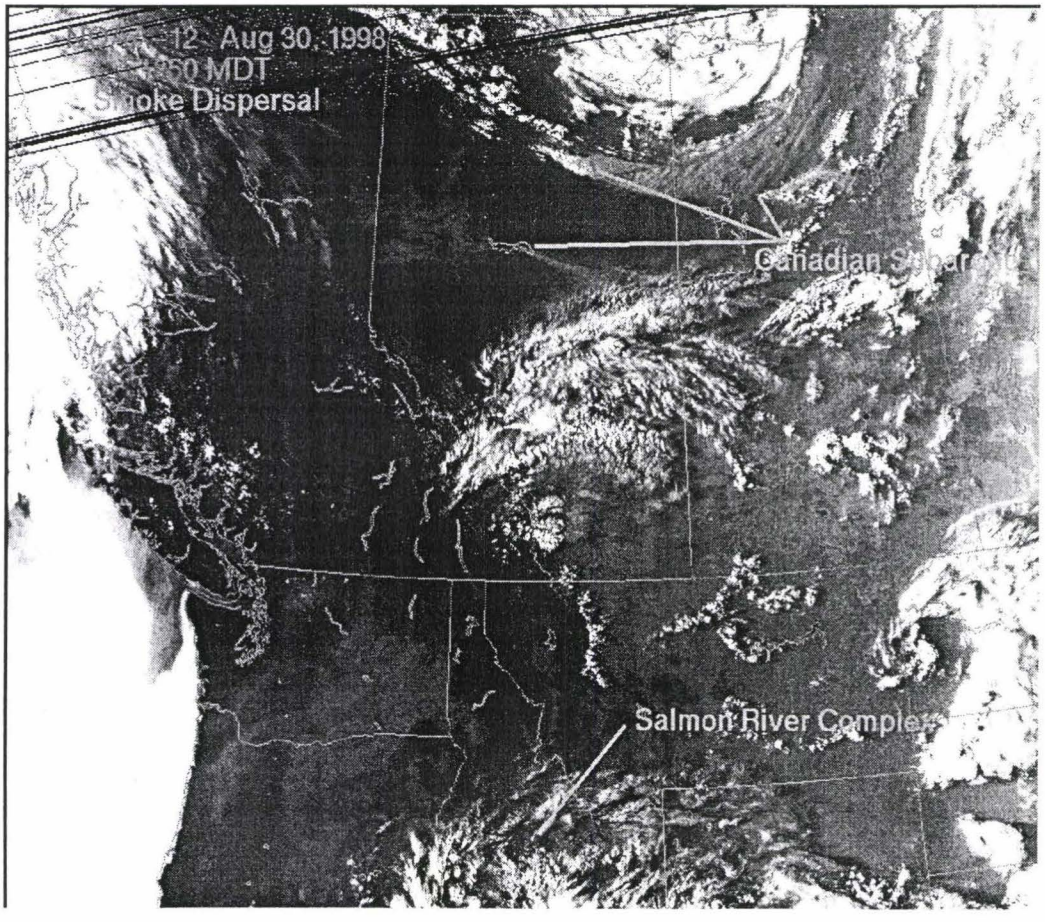


August 27, 1998 - 1817 MDT

As the high pressure system breaks down and retreats to the East, smoke associated with the frontal system covers almost all of the Columbia River Basin and Northern Rocky Mountain areas.



The origin of the smoke appears to be an Arctic low pressure system centered over Alaska, that with a counter clock-wise rotation, deposited smoke into the Gulf of Alaska from the large Canadian fires to the Southeast. This can be viewed if we go back four days to the World Wide Weather view prepared by WSICORP from the Internet on August 20, 1998 00:00 GMT showing the low pressure system over Alaska.



August 30, 1998 - 1850 MDT

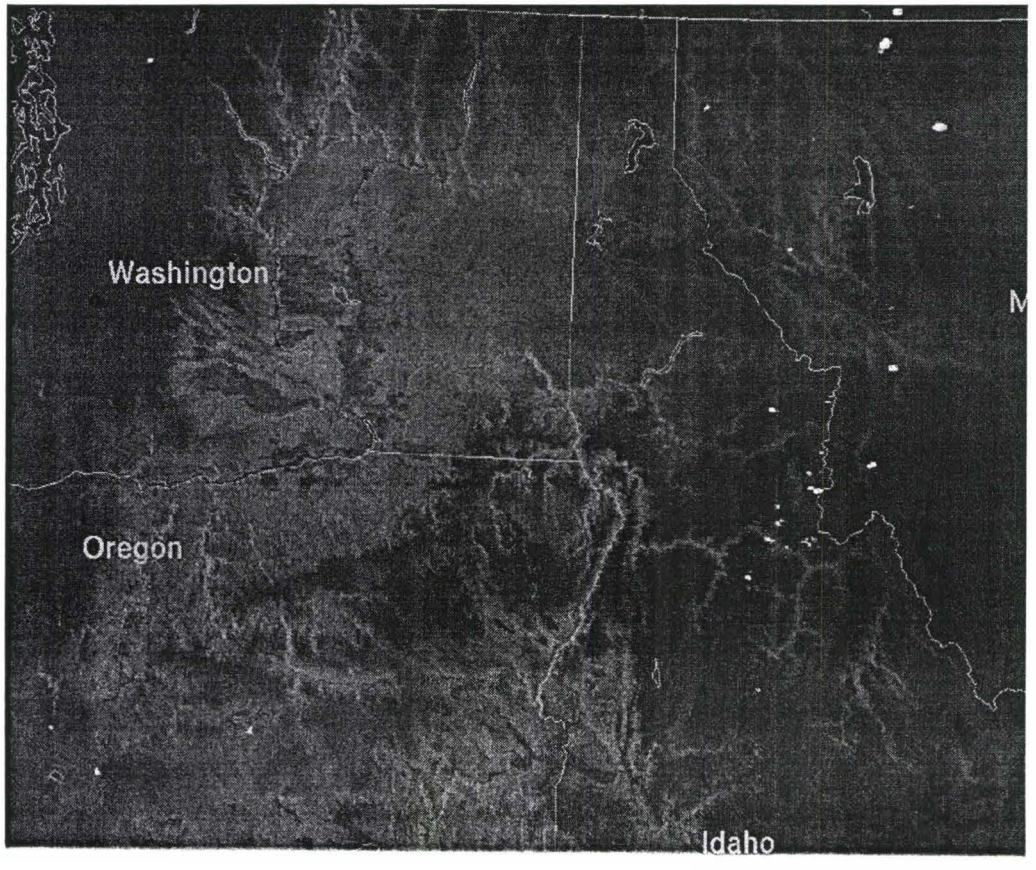
Note the residual smoke has re-entered the Canadian Provinces and the cycle appears to be repeating. Another Arctic low pressure system as begun sweeping the smoke from the large fires northward. The residual smoke in this sequence appears to have gone a full circle over the past 10 days.

THE EARLY SEPTEMBER 1998 FIRE WEATHER SEQUENCE

This sequence of images shows the effect of prescribed and natural wildfire smoke at peak season burning conditions. After a below normal wildfire season, the Northern Rocky Mountain area finally obtained fuel moisture and temperature conditions in September 1998 that would support large fires.

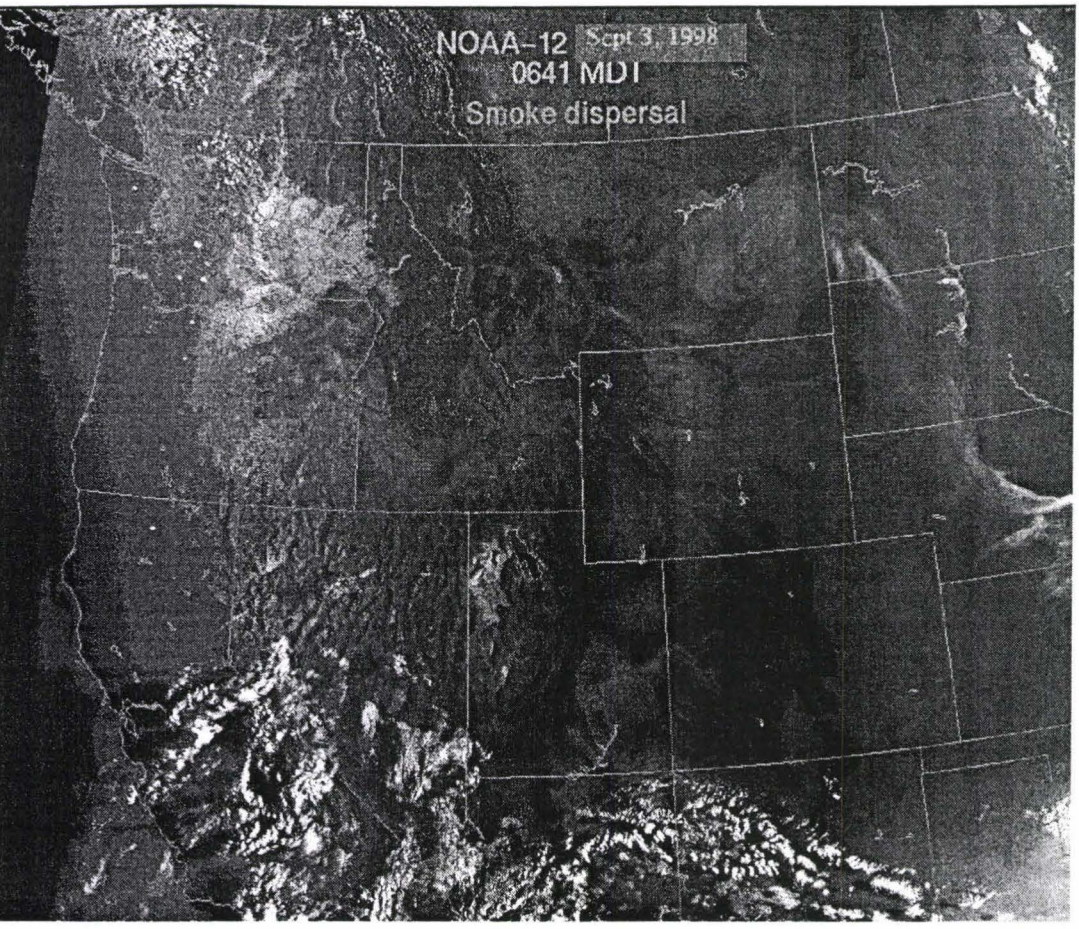
September 2, 1998 - 1925 MDT

A high pressure system centered over Eastern Washington and Northern Idaho is supporting a large conflation of fire in British Columbia, Central Idaho, and Western Montana. Note the smoke plumes trailing to the East and the rotation of these plumes to the Southeast around the clock-wise rotation of the high pressure system.



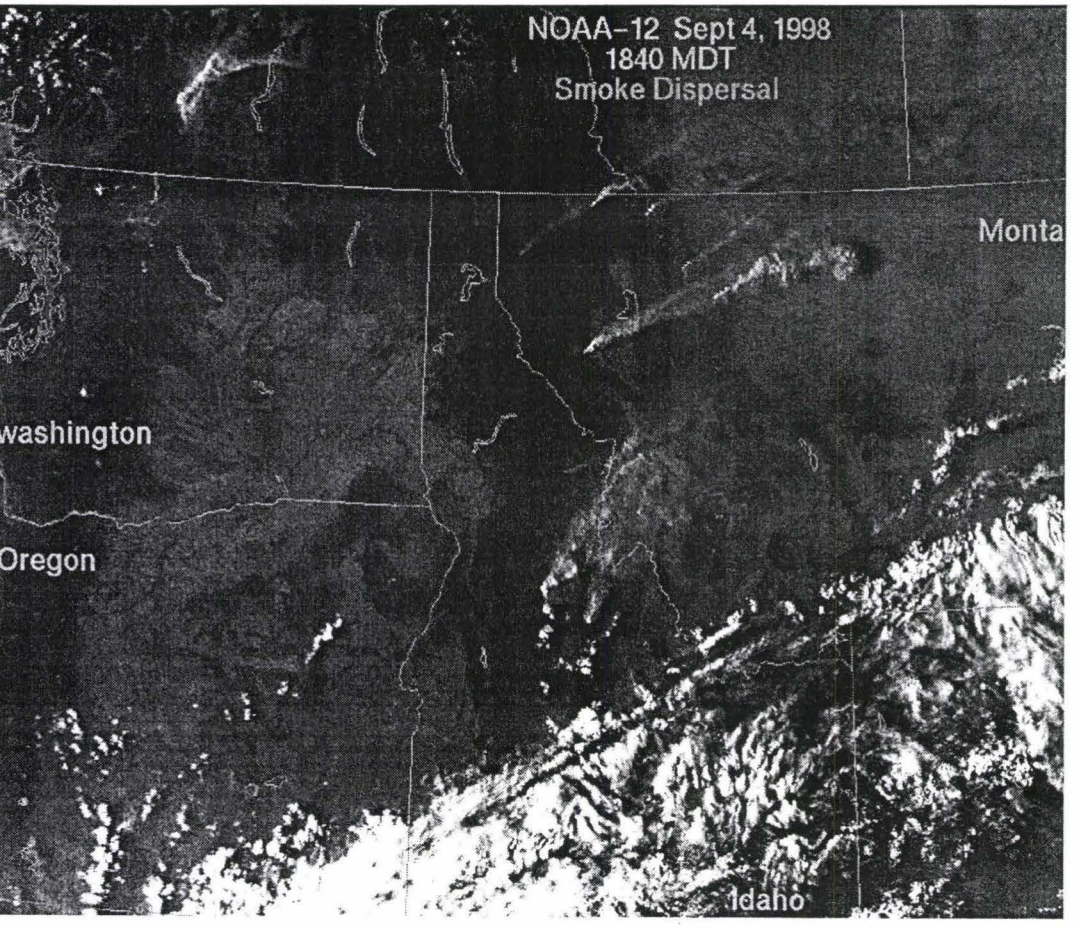
September 2, 1998 - 1925 MDT Infrared

This is an Infra Red view of the fire conflation.



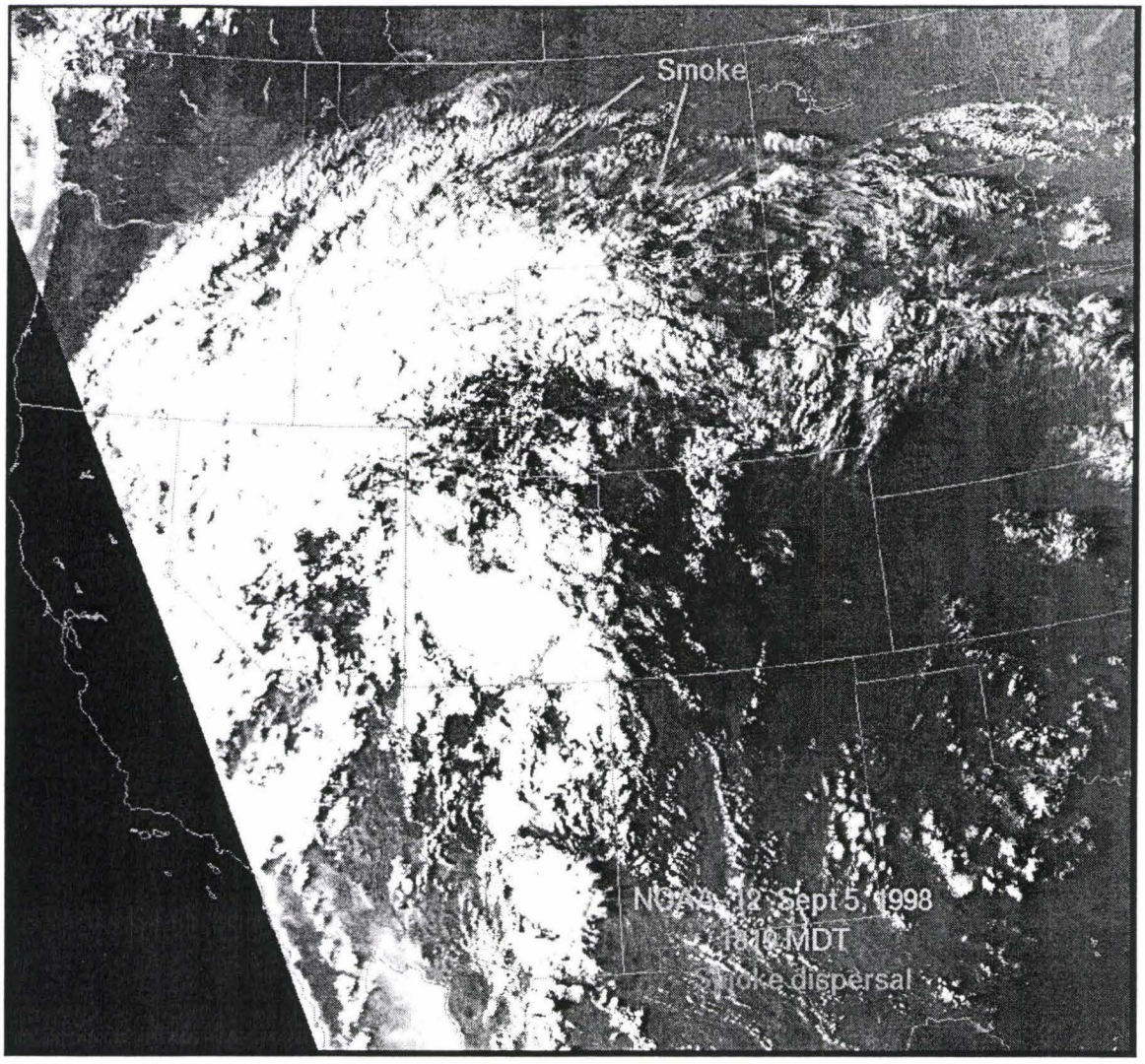
September 3, 1998 - 0641 MDT

Early morning view of the Northwestern United States. Note the fires have cooled down but the residual smoke is still consolidated and is passing throught the Dakotas and Nebraska, and then continuing Eastward. This is Band 4.



September 4, 1998 - 1840 MDT

Peak burn periods have occurred again. Note the tropical moisture (rotating clockwise) moving in from the South, and its affect on the fires and subsequent smoke.



September 5, 1998 - 1819 MDT

Tropical moisture has spread up to the Canadian border bringing moisture and high humidities. This basically was the end of the 1998 wildfire season.